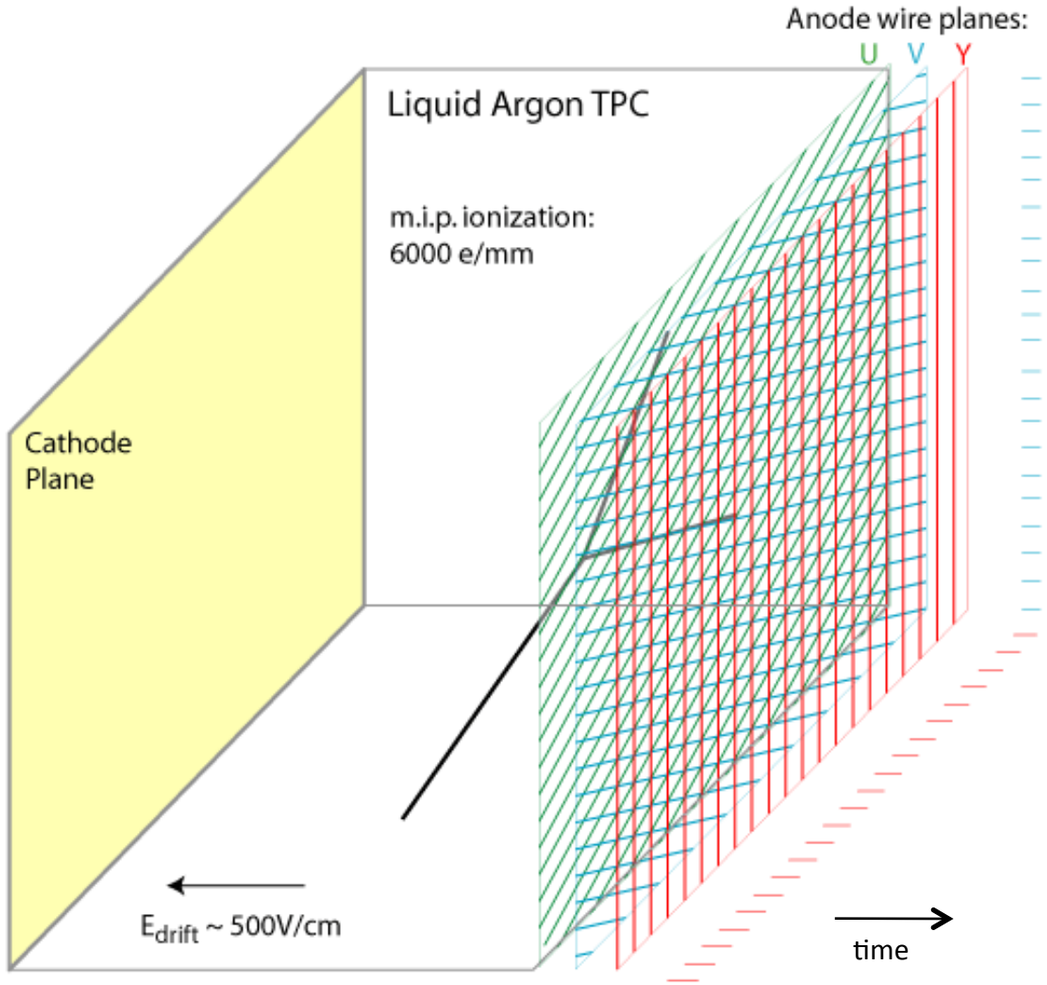
3D Reconstruction Using Charge

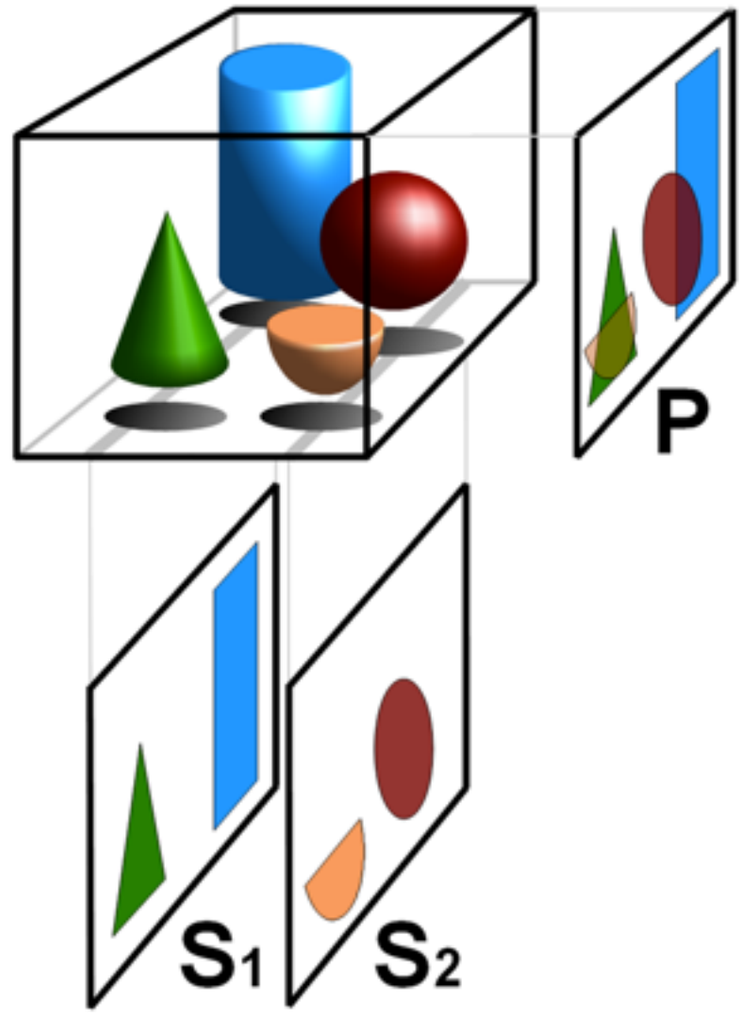
the “wire-cell” group

Outline

- Introduction of basic ideas to do tomographic 3D reconstruction using charge information
- Demo of some events
- Xin will describe some algorithms in more details if there is time left

TPC vs. Tomography



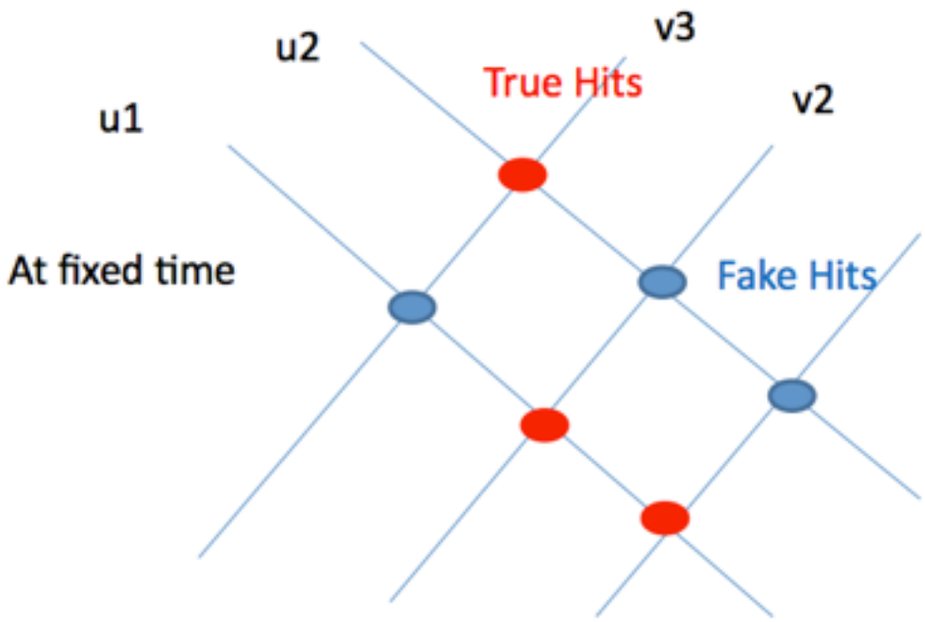


- As electrons drift toward APA, they represent tomographic cross sections at each time slice
- Combining the reconstructed images on the time slices results in the full 3D object

Fig.1:Basic principle of tomography: superposition free tomographic cross sections S1 and S2 compared with the projected image P

Challenge

- The challenge in large single-phase LArTPC reconstruction is the wire readout (compared with pad pixel readout):
  - Wire readout is necessary to reduce the cost
  - However the measured degree of freedom is reduced from N^2 (pixels) to “3N” (wires) ⟶ information lost

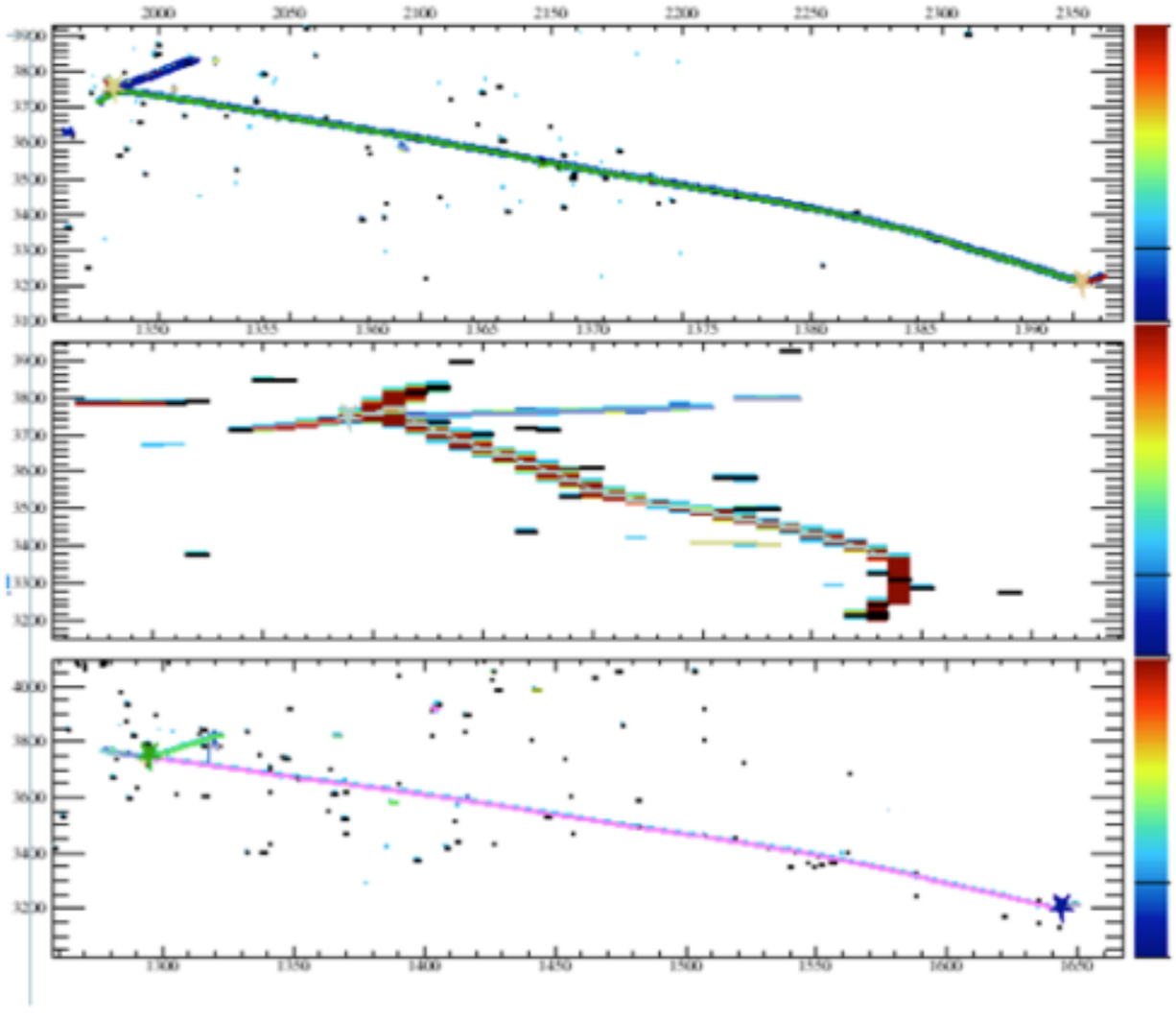


Use two-plane as an example

- Ambiguity is difficult to be totally removed
  - Faked hits when there are many hits at fixed time “t”

Traditional Solution

- Use the time information first
  - Track should be continuous in time
- Do tracking in 2-D (time vs. wire number)



- Combine three planes into a 3-D tracking
- Difficult for Shower, when there are many tracks
- 3D reconstruction is crucial for direction reconstruction, energy reconstruction as well as PID

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Our Approach

- Using charge to reduce degeneracy
  - Same charge in a “cell” is measured 3 times by wires on different planes

- Find out all potential hits including faked hits (H_i)
- We can then form a matrix

$$\begin{pmatrix} W_1^u \\ \dots \\ W_n^u \\ W_1^v \\ \dots \\ W_m^v \\ W_1^Y \\ \dots \\ W_k^y \end{pmatrix} = \begin{pmatrix} M_{u1}^{H1} & M_{u1}^{H2} & \dots & \dots & M_{u1}^{Hi} \\ & & & & \\ & & \bullet\bullet\bullet\bullet\bullet\bullet\bullet & & \\ & & & & \\ M_{yk}^{H1} & M_{yk}^{H2} & \dots & \dots & M_{yk}^{Hi} \end{pmatrix} \cdot \begin{pmatrix} H_1 \\ H_2 \\ \dots \\ H_{i-1} \\ H_i \end{pmatrix}$$

- This matrix is known
- It represents the knowledge
  - When there is a hit in 3D, we can predict definitely how much electrons are seen by each wire

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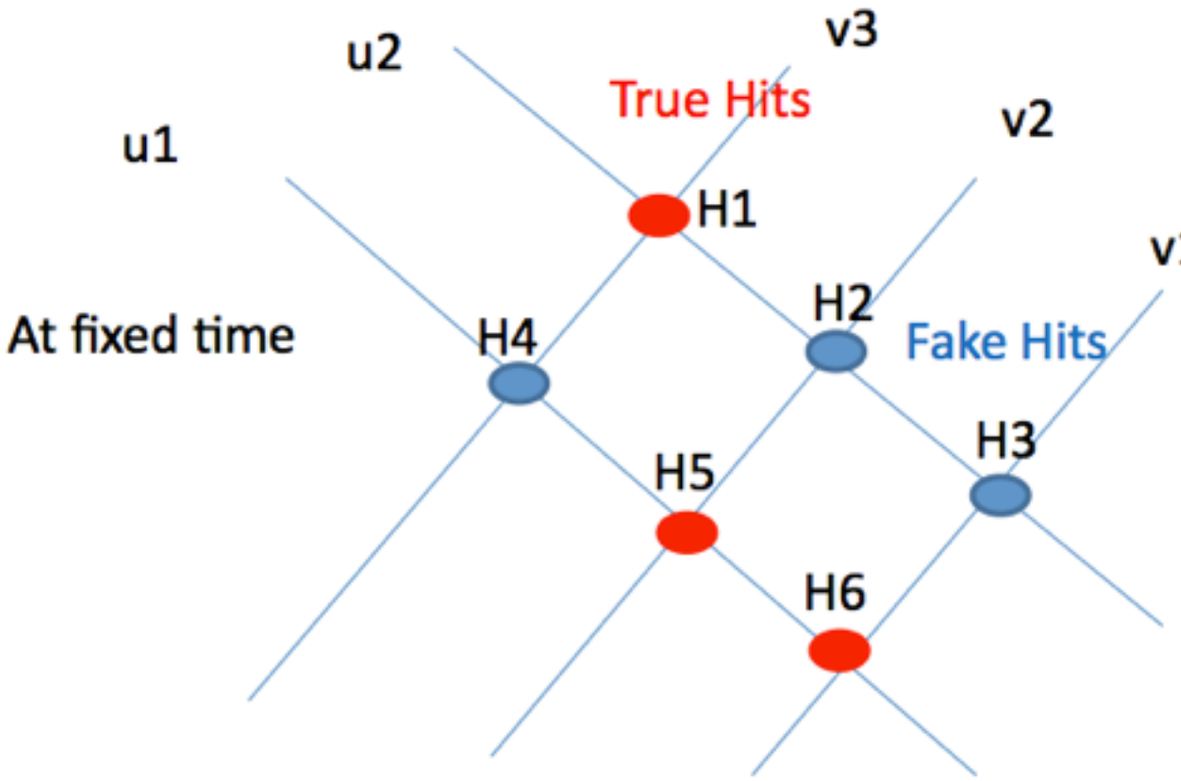
Example



$$\begin{pmatrix} u1 \\ u2 \\ v1 \\ v2 \\ v3 \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 & a & a & a \\ a & a & a & 0 & 0 & 0 \\ 0 & 0 & a & 0 & 0 & a \\ 0 & a & 0 & 0 & a & 0 \\ a & 0 & 0 & a & 0 & 0 \end{pmatrix} \cdot \begin{pmatrix} H_1 \\ H_2 \\ H_3 \\ H_4 \\ H_5 \\ H_6 \end{pmatrix}$$

There will be less faked hits with 3-plane readout
With charge in each point solved, fake hits would naturally have small (close to zero) charge

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Algorithms

- Construction of wire-cell association
- Concept of merged wire and merged cell
- χ^2 minimization and matrix Inversion
  - When not solvable, perform hypothesis testing, use information from near-by time layers to constrain number of unknowns
    - Exclusive Iterative approach
    - Markov-chain approach
- Merged Cell reduction
- Wrapped-wire configuration
- Clustering, tracking, and PID …

Blue: to do list

Xin will discuss in more details